



Adapting to Climate Variability, Thresholds, and Extremes in the Southwest

The Climate Assessment for the Southwest

June 1, 2015–May 31, 2016

Table of Contents

2015-16 CLIMAS Team.....	3
New Areas of Focus and Partnerships.....	4
New Regional Climate Services.....	5
CLIMAS Program Impact.....	6
Building Adaptive Capacity in the Southwest.....	7
2015-16 Top Accomplishment.....	7
Selected Research Findings.....	8
Outreach Activities.....	10
Key Publications.....	12
Selected Applications of CLIMAS Work.....	14
CLIMAS Contributions to the NIDIS Regional Drought Early Warning System 2015-16.....	15
2015-16 Publications.....	18

2015-16 CLIMAS Team

Principle Investigators: Heidi Brown, Bonnie Colby, Andrew Comrie, Michael Crimmins, David DuBois, Daniel Ferguson (Program Director; Lead PI), George Frisvold, Gregg Garfin, Jonathan Overpeck, Margaret Wilder, and Connie Woodhouse

Staff Researchers: Ben McMahan, Gigi Owen, Sarah LeRoy, and Emily Huddleston

Graduate Students: Joshua Albright, Rebecca Armenta, Ting Bai, Becky Brice, Suhina Deol, Kerrie Geil, Brewster Malevich, Trevor McKellar, Asumi Saito, Emilie Schur, Weide Wang, and Yizhi Zhao

Post-doctoral Researcher: Emery Eaves

Research Affiliates: Ardeth Barnhart, Julie Brugger, Jim Buizer, Zack Guido, Katharine Jacobs, Alison Meadow, Kiyomi Morino, and Jeremy Weiss

Climate & Society Fellows: *2015* – Christina Greene, Eric Magrane, Valerie Rountree, and Bhuwan Thapa; *2016* - Saleh Ahmed, Schuyler Chew, Stina Janssen, Sarah Kelly-Richards, and Joy Liu

New Areas of Focus and Partnerships

National Integrated Heat Health Information System – El Paso Region

CLIMAS Investigator: G. Garfin

The proposed initiative aims to increase preparedness and capacity to adapt to extreme high temperatures and heat waves in Rio Grande-Bravo Basin border cities by: a) identifying key heat health parameters and target populations for heat health early warning; b) creating a calendar of climate- and weather-related public health decisions; c) assessing capacity for coordinated heat health early warning; d) facilitating the sharing of best practices; and e) initiating development toward a community of practice within a network of regional cities.

Importance: This project explicitly connects CLIMAS with the NOAA-CDC National Integrated Heat Health Information System initiative and with an international network of similar projects aimed at implementing the Global Framework for Climate Services.

Additional support provided by: NOAA National Weather Service, NOAA Regional Climate Services Directors, Texas Tech University, and University of Texas at El Paso

Views of Drought across the Cattle Ranching Communities of Southwestern New Mexico and Northwestern Chihuahua

CLIMAS Investigator: D. DuBois

This project documents the historical and current drought status of rangeland areas used for cattle ranching across Southwestern New Mexico and Northwestern Chihuahua. Interviews will be conducted with ranchers in the US and Mexico facing these challenges. Interviews will be recorded, translated into English, edited, and included in a short video documentary. A report will accompany the video with data on the drought on both sides of the border and summaries of the interviews.

Importance: This project lays the groundwork for an assessment of drought impacts and needs for cattle ranchers in the Lower Rio Grande.

Additional support provided by: NIDIS – Coping with Drought

Preparing for High-Consequence, Low-Probability Events: Heat, Water & Energy in the Southwest

CLIMAS Investigators: G. Garfin and S. LeRoy

Higher summer temperatures projected for the Southwest will increase the demand for energy, especially during periods of peak load. Interactions between energy and water systems create additional vulnerabilities, including cascading impacts that affect public health and safety. A regional group of researchers and resource managers with expertise in water, energy, climate, natural hazards, and emergency management met on September 28-29, 2015, to address management and preparedness for high-impact, low-probability events.

Importance: This project brought together managers and researchers across various disciplines to discuss a topic that has not typically been considered when planning for extreme events—planning for unlikely scenarios that have the potential for very large, cascading impacts.

Additional support provided by: U.S. Bureau of Reclamation

Western Region Climate Services Database Development

CLIMAS Investigators: A. Meadow, B. McMahan, and G. Owen

Adapting to climate change requires that decision makers have information that is salient, credible, and legitimate. The research efforts in this project represent a first attempt to reduce the gap between the supply of and demand for climate information by creating a comprehensive Climate Centers

Evaluating Climate Change Adaptation in Tucson, AZ

CLIMAS Investigator: G. Owen

This project evaluates three case studies that address present and future risks and vulnerabilities related to climate change, focusing on the consumption of and access to food, water, and energy. One case study addresses current and future food security issues among children in Tucson, Arizona. The second assesses an electric utility company's process to ensure a reliable energy source for Tucson residents. The third case analyzes Tucson's initiatives for implementing green infrastructure for stormwater catchment and reuse.

Importance: The climate change adaptation community has identified a need to evaluate adaptation projects to help ground adaptation in practice rather than in theory. This project helps inform the best practices for evaluating adaptation.

New Regional Climate Services

Arizona – The Arizona Business Resilience Initiative: Part of this project involved conducting an assessment with an electric utility in southern Arizona targeted at heat, water availability, wildfire risk, and air quality concerns. The analysis was co-produced with utility employees and integrates GIS and spatial tools. The utility has used this information in revising their strategic resource plans such as energy portfolios, infrastructure planning, and land-use questions.

New Mexico – The Rio Grande-Bravo Outlook: This product provides information about recent climate events and trends, future forecasts, and seasonal outlooks for the Rio Grande-Bravo River Basin, a region that incorporates New Mexico and western Texas. The outlook is written in both Spanish and English and was first published in November 2015. It is produced monthly in collaboration with the NOAA Southern Region Climate Services director and the Southern Climate Impacts Planning Program. <http://www.climas.arizona.edu/rgbo>

Southwest Region – El Niño News & Information Hub: This climate service product is a repository for background information, news, and commentary regarding observed and expected El Niño impacts in the Southwest U.S. The hub was initiated in fall 2015 to help regional stakeholders prepare for the potential impacts of a strong El Niño event. <http://www.climas.arizona.edu/sw-climate/el-niño-southern-oscillation>

CLIMAS Program Impact

The CLIMAS program evaluation project has three overarching goals:

- Improve CLIMAS by measuring the impact of specific elements of the program and feeding those results back into program operations.
- Demonstrate the value of CLIMAS by assessing who values the program and how.
- Develop a set of metrics to identify the program's impacts and influence.

The four elements included in this evaluation are:

A) Outreach; B) Graduate and Undergraduate Training; C) Advancing Science Knowledge (e.g., peer-reviewed publications); and D) Use-Inspired Science and Decision Support

The broader research questions we propose to answer through program evaluation include:

- *Outreach*: How does CLIMAS outreach influence people's understanding of climate and/or climate impacts in the Southwest? How does CLIMAS outreach foster collaborative interactions between researchers and practitioners?
- *Graduate and Undergraduate Training*: What impact does CLIMAS have on future generations of researchers and practitioners?
- *Advancing Science Knowledge*: How and in what areas does CLIMAS advance scientific knowledge?
- *Use-Inspired Science and Decision Support*: Where on the spectrum of participatory research approaches do CLIMAS projects fit? How are the principles of participatory research applied to CLIMAS research? How does CLIMAS influence people's behavior (including decision making)?

Examples of metrics we are collecting for the program evaluation include:

Outreach: Interactions with media (newspaper, video, TV, etc., that is authored or produced by someone else); Online Contributions (produced by CLIMAS PIs for podcasts, blogs, news outlets, etc.); Presentations (including questions about the audience, why PIs decided to give the presentation, etc.); Social Media (substantive interactions on social media outlets)

Graduate and Undergraduate Training: Numbers of students enrolled in CESD program, applying for CLIMAS Fellowship, attending talks, employed as GRAs; Depth of knowledge about use-inspired science approaches.

Advancing Knowledge: Publications (peer-reviewed and not-peer-reviewed); Use of publications by academia (citations); Categorizing where articles are published (across disciplines); use of publications by stakeholders (applications).

Use-Inspired Science and Decision Support: Variable for each project. Interviewed each PI about their research, using logic model framework. Focus on outputs, and short- and medium-term outcomes. Most metrics in this section will be gathered from interviews with the intended stakeholders for each output.

Results-to-date:

We are currently collecting data regarding our program-level impact. This long-term data collection will allow us to understand broader program impact from 2012–17. Data collection deliverables to date include:

Outreach: Spreadsheets for each PI regarding media interviews given, online contributions written, presentations given, and workshops conducted. Spreadsheets include basic data,

motivating factors, intended audiences, and instances of further interaction for each outreach item.

Education and Training: Database of all graduate students who have interacted with CLIMAS since 2013 as a graduate research assistant, Climate & Society Fellow, or “Connecting Environmental Science and Decision Making” class participant.

Advancing Knowledge: Spreadsheets of all peer-reviewed and non-peer-reviewed publications produced since 2012.

Use-inspired science and decision support: Evaluation plans produced for at least one research project for each CLIMAS investigator.

Building Adaptive Capacity in the Southwest

This year, CLIMAS investigators responded to several types of climate service needs to help regional decision makers prepare and adapt to climate variability and change. Selected examples include:

- Further expansion into public health through the BRACE initiative (Building Resilience Against Climate Effects) and investigating climate impacts on vector-borne diseases.
- Assessing the climate information needs of the New Mexico Department of Transportation, which has concerns regarding dust storms and highway travel safety.
- Investigating the effects of increasing temperatures and extreme heat on the Southwest’s present and future sustainability. After analyzing CMIP-5 climate models, a local power utility incorporated this information into its strategic planning efforts.
- Collaborating with Hopi and Navajo land management agencies to inform tribal nation drought planning efforts.
- Investigating the climate information sources that irrigators use to make decisions.

2015-16 Top Accomplishment

One of CLIMAS’ top accomplishments this year was responding to information needs regarding the 2015-16 El Niño event. CLIMAS investigators organized a coordinated outreach effort in the months leading up to, during, and after El Niño. Through the *Southwest Climate Outlook*, climate podcasts, the *Southwestern Oscillations* blog, and the El Niño News & Information Hub, CLIMAS investigators explored: a) what was predicted to happen, including forecasts and outlooks, plus the media and public expectations for El Niño; b) what actually happened, including weather data and descriptions and case studies from people’s experiences of the event; and c) how stakeholders will use climate data and seasonal outlooks in the future. Several investigators were interviewed by local, regional, and national media outlets about what El Niño meant for the Southwest, demonstrating CLIMAS as a go-to source for regional climate information.

Selected Research Findings

Adaptation Strategies for Water and Energy Sectors in the Southwest

CLIMAS Investigators: B. Colby, G. Frisvold, C. Woodhouse, and G. Garfin

- Innovative water trading initiatives are underway in several western states. State legislatures and water management agencies have solicited testimony and requested workshops focused on the economic implications of these initiatives.
- Public agencies and NGOs have a better understanding of how to structure contracts with agricultural participants and how to measure and monitor water "savings" produced by participants.

Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information

CLIMAS Investigator: G. Frisvold

- Agriculture's water footprint—the amount of water needed to produce a given amount of crop—in the Southwest has declined significantly. Reductions in water use for cotton production have declined by an amount equivalent to two-thirds of all residential water use in those states.
- Improvements in local hydrological data reveal that earlier estimates regarding the water footprint of Arizona wheat production were wrong. Due to high yields and adjustments in seasonal production patterns to conserve water, Arizona now has one of the world's smallest water footprints.
- Climate information systems have shown great promise in improving irrigation management and adaptation to climate variability, but the many farmers who have limited access to the Internet may seldom use web-based information systems.

CLIMAS Heat Extremes Assessment (HEAT) – Exploring the Cascading Effects of Climate Extremes in the Southwest

CLIMAS Investigator: B. McMahan

- Acute heat waves and exposure remain a fundamental concern for vulnerable populations but ongoing project work continues to elaborate on chronic or long-term issues associated with climate and environmental risk in the Southwest, which intersect and amplify acute, shorter-term risks.

Western Region Climate Services Database Development

CLIMAS Investigator: A. Meadow

- Most climate service providers included in this database (79/136) are focused on delivering climate and weather information. A much smaller percent of providers appear to be offering services related to interpreting or applying that information.
- In comparison to the number of tribes in NOAA's Western Region (231 tribes), only 17 climate service providers target their services or information to tribes.

Southwest Climate Gap

CLIMAS Investigators: M. Wilder, D. DuBois, and B. McMahan

- A significant climate gap exists in the Southwest due to extreme climate conditions coupled with high socioeconomic vulnerability in the region.
- Low-income communities in southern Arizona adapt to extreme heat by staying indoors, which has implications for public health and sustainability.

Disentangling the Influence of Antecedent Temperature and Soil Moisture on Colorado River Water Resources

CLIMAS Investigator: C. Woodhouse

- Major upper Colorado River droughts of the 20th and 21st centuries have occurred under various combinations of precipitation, temperature, and prior fall soil moisture.
- The 2000s drought (2000–12) was the least dry (precipitation at the 48th percentile), but the warmest (79th percentile). The 1988–96 drought was also only moderately dry but quite warm.

Outreach Activities

CLIMAS Website (www.climas.arizona.edu)

General website summary: From June 1, 2015–May 31, 2016, the CLIMAS website had approximately 90,000 page views.

- The Southwest Climate pages garnered 30 percent of total traffic, while 14 percent of traffic went to the publications pages. Eleven percent of traffic was directed towards the *Southwest Climate Outlook*, 8 percent for the *Southwestern Oscillations* blog, 4 percent for research and project pages, and 2 percent for the podcast.
- The top sub-domains of the website focused on interest in the ongoing El Niño event (15 percent of total traffic); the monsoon (17 percent of total traffic); and Southwest temperature, precipitation, and drought (~7 percent of total traffic).

Southwestern Oscillations: News, Information, & Commentary (The CLIMAS Blog)

Climate Investigators: B. McMahan, M. Crimmins, G. Garfin, D. Ferguson, G. Frisvold, H. Brown, E. Huddleston, Z. Guido, and G. Owen

Southwestern Oscillations is an ongoing source of engagement with the general public and other scientists/practitioners. It is the hub for news, information, and commentary about CLIMAS research and climate-related issues. This blog is updated regularly to distribute news, updates, and other information on CLIMAS research projects and publications.

The blog reinforced this year's pattern of increased interest about El Niño; the most trafficked post was an extended explanation of the potential impact of a strong El Niño event on the Southwest. A number of other posts saw more normal traffic, with 100 to 500 visits per blog post. <http://www.climas.arizona.edu/blog>

El Niño News & Information Hub

Climate Investigators: Ben McMahan, M. Crimmins, E. Huddleston, G. Owen, and H. Brown

The El Niño News & Information Hub connects climate information to potential and observed impacts of the 2015–16 El Niño event. This project integrates multimedia outreach (web, podcast, blog, and print) with climate assessment and analysis to create content that might be of interest to other scientists, resource managers, policymakers and decision makers, and an interested public. This year, 10 unique pieces of content were produced in addition to the *El Niño Tracker* in the *Southwest Climate Outlook* and the Southwest Climate Podcasts.

The hub experienced higher traffic around times of increased forecast frequency and media attention (fall 2015), tropical storm activity tied to El Niño (October–November 2015), and early 2016 storms that were attributed to El Niño (January 2016).

Southwest Climate Podcasts

Climate Investigators: B. McMahan, M. Crimmins, G. Frisvold, B. Colby, D. Ferguson, G. Garfin, E. Huddleston, and Z. Guido

El Niño, the monsoon, increasing temperatures, and dwindling reservoir storage are just a few of the climate-related issues that periodically punctuate the news cycle in the Southwest. CLIMAS scientists discuss these issues in monthly climate podcasts and special podcast series. Podcasts

received between 100 and 300 visits to the page. Listeners who syndicate the downloads via a podcast app or iTunes are not reflected in these numbers.

<http://www.climas.arizona.edu/media/podcasts>

- *Southwest Climate Podcast* is produced monthly, synthesizing information from disparate sources, and translating national and global discussions into what they mean for the Southwest.
- *Southwest Climate Update-Mini Podcast* focuses on quick and timely reporting of important climate news and information. It emphasizes stories that relate to the Southwest that illustrate the impact of climate on national or global scales. This podcast is also released as a video on the CLIMAS YouTube channel.
- *Speaking of Climate...* includes conversations with researchers and stakeholders about climate-related issues. Distributed on the CLIMAS listserv, CLIMAS blog, Twitter, Facebook, and YouTube.

Other funding: NIDIS – Coping with Drought

The Southwest Climate Outlook

Climate Investigators: B. McMahan, G. Garfin, M. Crimmins, D. DuBois, and E. Huddleston

The *Southwest Climate Outlook* (SWCO) summarizes climate and weather information from disparate sources in nonscientific language, providing more than 1,600 people with timely climate-related information. Since SWCO's inception in 2002, the publication has evolved into a tool for two-way communication with stakeholders and a platform for responding to needs throughout the region.

Other funding: NIDIS – Coping with Drought

Notable Outreach Interactions on Social Media

June 1–Aug. 30, 2015: Engagements centered on regional/seasonal climate forecasts, El Niño-specific forecast discussions, and specific outlier events. The most notable interactions on social media responded to El Niño forecasts and reflected the anticipation for a not-yet-started ENSO event that was building in strength.

Sept. 1–Nov. 30, 2015: Engagements centered on El Niño, given the forecast potential of a record to near-record event, and on discussion about a specific tropical storm event that produced impressive moisture totals in the region. The National Weather Service office in Tucson (@NWSTucson) used CLIMAS graphics on Twitter to review the end of the 2015 monsoon.

Dec. 1, 2015–Feb. 29, 2016: Engagements centered on the performance of El Niño to date, as this three-month window began to capture some of the increased winter storm activity as well as the subsequent disappointment about the performance of El Niño. Top engagements focused on the relative “average” status of the winter’s precipitation and whether this met expectations for the season. The partnership with the *Rio Grande-Bravo Climate Outlook* also began to generate activity and dialogue.

Mar. 1–May 30, 2016: This three-month window showed a notable shift towards disappointment and retrospective analysis of the El Niño event, based on how it performed compared to expectations, as well as ongoing commentary as to how far this particular event deviated from general expectations, specific models, and seasonal outlooks.

Key Publications

Routson C., **J. Overpeck**, **C. Woodhouse**, and W. Kenney. 2016. Three Millennia of Southwestern North American Dustiness and Future Implications. *PLOS ONE* 11(2):e0149573.

A 3,000-year record of drought and atmospheric dust loading indicates that multi-decadal drought can cause widespread destabilization of vegetation and soils, yielding increases in regional dust loading of the type that can cause human health issues and decreases in Colorado River flow.

Woodhouse, C., G. Pederson, K. Morino, S. McAfee, and G. McCabe. 2016. Increasing influence of air temperature on upper Colorado River streamflow. *Geophysical Research Letters* 43. doi:10.1002/2015GL067613.

This article uses paleoclimatic data for the Colorado River Basin to extend instrumental climate and flow records, along with climate change projections to assess the range of possible conditions that may be expected to occur and to determine how warming temperatures may influence river flow and water supply in the future.

Frisvold, G. 2015. Water, Agriculture, and Drought in the West Under Changing Climate and Policy Regimes. *Natural Resources Journal* 55:293-328.

<http://lawschool.unm.edu/nrj/volumes/55/2/NRJ-55-2-Frisvold.pdf>

Technological fixes to conserve and transfer agricultural water to other uses will likely fail to facilitate climate adaptation unless changes in water management institutions, policies, and economic incentives accompany those technological fixes. The article provides information on agriculture, water, and climate adaptation to western lawyers and law students. It also provides information to the USDA about barriers to the adoption of climate adaptation information from their climate hubs.

Duval, D. and **B. Colby.** 2015. *The Influence of Colorado River Flows on the Upper Gulf of California Fisheries Economy*. Report to the Sonoran Institute, July.

This report examines existing and potential economic effects and values for Upper Gulf of California marine ecosystems as linked to the effects of freshwater flows from the lower Colorado River and the implementation of Minute 319 in providing flows. It provides a methodological framework for measuring economic effects of having higher flow levels and the implications for Upper Gulf communities.

Brown, H., A. Young, J. Lega, T. Andreadis, J. Schurich, and **A. Comrie.** 2015. Projection of climate change influences on U.S. West Nile virus vectors. *Earth Interactions* 19:1-18. doi: <http://dx.doi.org/10.1175/EI-D-15-0008.1>

This article provides location-specific information about West Nile virus mosquito abundance as it relates to climate.

Meadow, A., Z. Guido, M. Crimmins, and J. McLeod. 2016. From principles to action: Applying the National Research Council's principles for effective decision support to the Federal Emergency Management Agency's watch office. *Climate Services* 1:12–23. doi: 10.1016/j.cliser.2016.02.002

This paper describes the methods used for planning and executing a three-party collaborative effort to provide climate services, a decision support tool developed through this process, and the lessons taken from this collaborative process.

Kavouras, I., **D. DuBois**, G. Nikolich, A. Corral Avittia, and V. Etyemezian. 2015. Particulate dust emission factors from unpaved roads in the U.S.-Mexico border semi-arid region. *Journal of Arid Environments* 124:189–192. doi: <http://dx.doi.org/10.1016/j.jaridenv.2015.07.015>

Fugitive dust in the border cities of Las Cruces, New Mexico; El Paso, Texas; and Ciudad Juarez in Mexico presents challenges for air quality managers due to their variability in space and time. The study was conducted to provide site-specific PM10 emission rates of unpaved roads in areas that have been deemed problematic by local authorities and the public.

Ferguson, D., A. Masayesva, A. Meadow, and M. Crimmins. 2016. Rain gauges to range conditions: Collaborative development of a drought information system to support local decision making. *Weather, Climate and Society*. Early online release. <http://dx.doi.org/10.1175/WCAS-D-15-0060.1>

This report is framed on collaborative work with the Hopi Tribe to develop a drought information system that: 1) is based on how drought is experienced by Hopi citizens and resource managers; 2) incorporates local observations of drought impacts as well as conventional indicators; and 3) brings together local expertise with conventional science-based observations.

Wilder, M., D. Liverman, L. Bellante, and T. Osborne. 2016. Southwest climate gap: Poverty and environmental justice in the U.S. Southwest. *Local Environment: The International Journal of Justice and Sustainability* 1-22. doi: <http://dx.doi.org/10.1080/13549839.2015.1116063>

How does the southwestern climate—especially heat/cold extremes and precipitation associated with El Niño—affect low-income populations and communities of color in the Southwest? This article answers this question by analyzing 20 interviews that were conducted with 15 organizations that provide services to low-income populations.

LeRoy, S., G. Garfin, and M. Black. 2016. Anticipating Cascading Effects from Climate Extremes. *EOS* 97. doi:10.1029/2016EO048971

This meeting report outlines the High-Consequence, Low-Probability workshop held in fall 2015. It summarizes the key findings, including research, management, and planning priorities identified by participants. <https://eos.org/meeting-reports/anticipating-cascading-effects-from-climate-extremes>

Selected Applications of CLIMAS Work

Climate and Health

Climate Investigators: A. Comrie and H. Brown

This project develops and implements a climate-based Dynamic Mosquito Simulation Model (DyMSiM) to understand and project climate effects on mosquito population dynamics and associated implications for public health. DyMSiM has had a broad impact. Recently it was implemented in a rapid-response study that included University of Arizona colleague Kacey Ernst and CLIMAS alumnus Cory Morin. The study outlined the seasonal occurrence and abundance of the Zika virus vector mosquito for the U.S. Ernst recently gave public testimony to the U.S. House of Representatives Committee on Science, Space and Technology, Subcommittee on Research and Technology regarding current knowledge of *Aedes aegypti* in the U.S. related to the Zika virus.

Exploring the Use of Climate and Remote Sensing Data to Support Drought Monitoring across the Southwest U.S.

CLIMAS Investigator: M. Crimmins

DroughtView combines geovisualization tools with remote sensing products to detect drought conditions. Engaging the range management and rancher community on this tool heavily over the past year and has yielded positive feedback on the utility of using remote sensing for drought monitoring in remote areas. Ranchers are interested in using the tool to track potential conditions on remote pastures/allotments that are difficult to get to. There is also interest in using DroughtView in formal drought assessments and planning efforts with the U.S. Forest Service.

Air Quality and Climate

CLIMAS Investigator: D. DuBois

Dust storms in the Southwest U.S. and northern Mexico continue to be a serious health and safety issue. The construction of a synoptic climatology of these dust storms began this year to increase the ability to forecast these events. The New Mexico Department of Transportation (DOT) has increased its interest in public safety and mitigation of dust. The DOT staff has since requested and obtained federal funding for mitigation and public notification projects.

The Southwest Climate Outlook

CLIMAS Investigator: B. McMahan

The *Southwest Climate Outlook* (SWCO) summarizes climate and weather information from disparate sources in nonscientific language, providing more than 1,600 people with timely climate-related information. The reservoir diagrams in the monthly SWCO are used by members of the New Mexico Office of the State Engineer and the Interstate Stream Commission in presentations by the executive director to the New Mexico Legislature.

CLIMAS Contributions to the NIDIS Regional Drought Early Warning System 2015-16

Several CLIMAS projects contributed to developing capabilities and methodologies to advance drought early warning systems in the Southwest U.S. Projects are categorized below:

Convene and collaborate with regional stakeholders

Southeast Arizona Agricultural Weather and Climate Working Group: University of Arizona Cooperative Extension and the National Weather Service-Tucson have developed a working group focused on engaging the agricultural community of Southeast Arizona to assess information needs, provide training opportunities and technical support, and conduct applied research and develop new and enhanced decision support tools.

Improve regional to local capabilities to understand, educate and communicate drought information and awareness

Views of Drought across the Cattle Ranching Communities of Southwestern New Mexico and Northwestern Chihuahua: This project documents the historical and current drought status of the rangeland areas that are used in cattle ranching across Southwestern New Mexico and Northwestern Chihuahua. It also lays the groundwork for an assessment of drought impacts and needs for cattle ranchers in the Lower Rio Grande.

Western Adaptation Alliance – A Collaboration Project for Adaptation and Resilience to Climate Extremes: This project assists regional urban network managers of the Western Adaptation Alliance in communicating with key constituencies in their communities to broaden support for action on climate adaptation, and to improve preparedness.

Demonstrate drought risk reduction strategies using drought monitoring and prediction information in partnership with users and federal, state, regional, and local agencies

Air Quality and Climate: Dust storms in the Southwest US and Northern Mexico continue to present serious health and safety issue. This project continues surveillance of dust storms and determines their latitude and longitude. Work is underway to develop a synoptic climatology of these dust storms to increase the ability to forecast these events.

Exploring the use of climate and remote sensing data to support drought monitoring across the Southwest U.S.: This project involves further development of a web tool called DroughtView that combines online geovisualization tools with derived remote sensing products targeting at detecting drought conditions. DroughtView builds on the success of a precursor effort called RangeView that was developed with the guidance of agriculturists and resource managers with a need for environmental monitoring data. The tools in DroughtView are currently being used to monitor biweekly changes in land surface greenness conditions as a proxy for drought impacts at very fine spatial scales across the Southwest U.S.

Improve the usefulness of drought indicators and prediction products for drought preparedness.

Planning for Drought in the Warming and Drying Southwest: Developing a Suite of Drought Indicators to Support Tribal Decision Making in the Four Corners: The goal of this project is to work with the Hopi Tribe's Department of Natural Resources

(HDNR) to develop a set of drought indicators and approaches for collecting, analyzing, and utilizing the data needed to support each indicator. Work this year focuses on assessing the impact of daily scale precipitation and temperature variability on modeled seasonal soil moisture regimes for the Four Corners region with the ultimate goal being a better understanding of which drought metrics may be best utilized for characterizing rangelands and dryland farming areas.

Deliver products and services at regional and local scales

The Southwest Climate Outlook: The *Southwest Climate Outlook* (SWCO) summarizes climate and weather information from disparate sources in nonscientific language, providing more than 1,600 people with timely climate-related information. Since SWCO's inception in 2002, stemming from the END InSight project, the publication has evolved into a tool for two-way communication with stakeholders and a platform for responding to needs throughout the region.

Southwest Climate Podcasts: El Niño, the monsoon, increasing temperatures, and dwindling reservoir storage are just a few of the climate-related issues that periodically punctuate the news cycle in the Southwest. CLIMAS scientists discuss these issues in monthly climate podcasts and special podcast series. The podcasts synthesize information from disparate sources that often do not have a Southwest bent, translating the national and global discussions into what it means for the Southwest. The podcasts also add insight to the discussions by bringing in latest climate science, covering climate-related topics with nuance but not shrouded in technical jargon.

Evaluate drought risk communication and drought risk reduction strategies around the impacts of extreme events and overall resilient development practices

Adaptation to Climate Variability and Change: Markets, Policy, Technology, and Information: This project examines the role of water management information and irrigation technologies in agricultural adaptation to climate variability and change in the 17 westernmost US states. The project conducts statistical analysis to examine how factors such as farm size, water costs, and drought affect demand for water management information. For Arizona specifically the project examines trends in agricultural water management, investments in irrigation improvements, and water productivity (e.g., agricultural output per unit of water applied, or “crop per drop”).

Adaptation Strategies for Water and Energy Sectors in the Southwest: This project examines potential climate change and variability adaptation strategies related to water and energy in the Colorado River and Rio Grande Basins, including northwestern Mexico. Researchers are investigating how climate influences the market price of water and are developing a menu of water and energy supply reliability tools and guidelines for using these tools to enhance supply reliability.

CLIMAS Heat Extremes Assessment (HEAT) – Exploring the Cascading Effects of Climate Extremes in the Southwest: Climate extremes pose serious threats to human health, increase demands on municipal services and infrastructure, and threaten the long-term regional sustainability. These extremes have implications for rapid response and emergency

management, but they also amplify the effects of underlying social, economic, and environmental vulnerabilities, and have numerous potential long-term consequences in terms of planning-for, and dealing-with, potential disasters. In this project, we are assessing how underlying climate risk intersects with acute events to create cascading impacts. Project goals include a regional assessment of vulnerabilities to climate extremes that will establish a set of CLIMAS research and climate services priorities.

Sectoral Impacts of Drought and Climate Change: This project examines the impacts of drought and climate change on climate sensitive sectors in the Southwest, focusing on agriculture as well as outdoor recreation and tourism. In response to frequent stakeholder requests, the project examines how water transfers would affect the local economies or rural, water-exporting communities. The project examines how drought and climate change would affect acquisition of water for environmental restoration. It also considers how combining agronomic information with seasonal weather forecasts can assist the use of option contracts to reduce water supply risks. Work this year will focus on analysis to understand how a shortage on the Colorado River might impact the agricultural economy in Yuma and central AZ. The project team is also looking at rates of cropland abandonment in the face of drought across much of the southern US.

Using Critical Thresholds to Customize Climate Projections of Extreme Events to User Needs and Support Decisions: Many communities are already vulnerable to extreme events, and many of these vulnerabilities will increase with climate change. Identifying and better understanding critical thresholds for extreme events is key to developing effective community responses to climate change. This project will test a methodology for using a participatory process to define critical thresholds for extreme events and use these thresholds to customize climate projections to community-specific needs.

2015-16 Publications

- Armenta, R. 2016. *Geopotential Height Patterns at 500mb Associated with Major Dust Storms in the United States/Mexico Border Region During January-May of 2011-2014*. Master's thesis. New Mexico State University.
- Brown, H., A. Young, J. Lega T. Andreadis, J. Schurich, and A. Comrie. 2015. Projection of climate change influences on U.S. West Nile virus vectors. *Earth Interactions* 19(18):1-18. doi: <http://dx.doi.org/10.1175/EI-D-15-0008.1>
- Brown, H., M. Roach, G. Smith, M. Wilder, S. Chambers, I. Patten, and Q. Rabby. 2016. *Assessment of Climate and Health Impacts on Vector-Borne Diseases and Valley Fever in Arizona*. Report to Arizona Department of Health Services.
- Colby, B. 2015. *Lower Rio Grande Groundwater Banking White Paper*. Report to New Mexico Interstate Stream Commission.
- Colby, B. 2016. *Using Surveys to Inform Design and Implementation of System Conservation Programs*. Report to U.S. Bureau of Reclamation.
- Colby, B. 2016. *Developing System Conservation Programs: A Guide For The Bureau Of Reclamation And Partner Organizations*. Report to U.S. Bureau of Reclamation.
- Colby, B. (In press). Water Trading Innovations: Reducing Agricultural Consumptive Use to Improve Adaptation to Scarcity. In Ziolkowska, J., and J. Peterson (eds.). *Competition for Water Resources: Experiences and Management Approaches in the US and Europe*.
- Colorado River Research Group. 2016. *Prioritizing Management and Protection of the Colorado River's Environmental Resources*. White paper. Editors include J. Overpeck and B. Colby. http://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg_environmental_management.pdf
- Colorado River Research Group. 2015. *A Look at the Interim Guidelines at their Mid-Point*. White Paper. Editors include J. Overpeck and B. Colby. http://www.coloradoriverresearchgroup.org/uploads/4/2/3/6/42362959/crrg_interim_guidelines_white_version_updated2.pdf
- Crimmins, M., D. Ferguson, J. Weiss, and H. Faulstich. 2015. *Hopi Climate: An Overview to Support Drought Monitoring and Management*. Tucson, AZ: Climate Assessment for the Southwest.
- Duval, D. and B. Colby. (In press). Colorado River Flows and the Fisheries Economy of the Upper Gulf of California. *Ecological Engineering*.
- Duval, D., A. Kerna, G. Ruyle, L. Howry, and G. Frisvold. (In press). *Economic Impact of Cooperative Extension Efforts in Rangeland Management for Northern Arizona Ranching Allotment*. Working Paper. Arizona Cooperative Extension.
- Duval, D. and B. Colby. 2015. *The Influence of Colorado River Flows on the Upper Gulf of California Fisheries Economy*. Report to the Sonoran Institute.
- Kerna, A., B. Colby, and F. Zamora. (In press). Valuing Environmental Flows in Mexico's Colorado River Delta. *Water Economics and Policy*.

- Ferguson, D., A. Masayesva, A. Meadow, and M. Crimmins. 2016. Rain gauges to range conditions: Collaborative development of a drought information system to support local decision making. *Weather, Climate and Society*. Early online release. <http://dx.doi.org/10.1175/WCAS-D-15-0060.1>
- Ferguson, D. and M. Crimmins. 2016. *Improved Drought Monitoring and Planning for the Hopi Tribe: Final Report*. Tucson, AZ: Climate Assessment for the Southwest.
- Ferguson, D., M. Finucane, V. Keener, and G. Owen. 2016. *Evaluation to Advance Science Policy: Lessons from Pacific RISA and CLIMAS*. In Parris, A., G. Garfin, K. Down, R. Meyer, and S. Close (eds.). *Climate in Context: Science and Society Partnering for Adaptation*. New Jersey: Wiley Ltd. & Sons, p. 215-233.
- Frisvold, G. 2015. Water, Agriculture, and Drought in the West Under Changing Climate and Policy Regimes. *Natural Resources Journal* 55: 293-328. <http://lawschool.unm.edu/nrj/volumes/55/2/NRJ-55-2-Frisvold.pdf>
- Frisvold, G. 2015. *Developing Sustainability Metrics for Water Use in Arizona Small Grain Production Final Report to the Arizona Grain Research and Promotion Council*. Phoenix, AZ: Arizona Department of Agriculture. https://agriculture.az.gov/sites/default/files/Final__15-03.pdf
- Frisvold, G. 2016. *Trends and patterns of water use in cotton production. Proceedings of the Beltwide Cotton Conferences*. Memphis, TN: National Cotton Council. <https://www.cotton.org/beltwide/index.cfm?page=proceedings>
- Garfin, G. and S. LeRoy. 2015. *Extreme Heat Toolkit – Resources Document*. Tucson, AZ: CLIMAS, 47 pp.
- Garfin, G., S. LeRoy, B. McMahan, M. Black, and B. Roh. 2016. *Preparing for High-Consequence, Low-Probability Events: Heat, Water & Energy in the Southwest*. Report to the U.S. Bureau of Reclamation from the project, Enhancing Water Supply Reliability. The University of Arizona.
- Kavouras, I., D. DuBois, G. Nikolich, A. Corral Avittia, and V. Etyemezian. 2015. Particulate dust emission factors from unpaved roads in the U.S.-Mexico border semi-arid region. *Journal of Arid Environments* 124:189–192. doi: <http://dx.doi.org/10.1016/j.jaridenv.2015.07.015>
- LeRoy, S., G. Garfin, and M. Black 2016. Anticipating cascading effects from climate extremes. *EOS* 97. doi: 10.1029/2016EO048971. <https://eos.org/meeting-reports/anticipating-cascading-effects-from-climate-extremes>
- LeRoy, S. and G. Garfin. 2015. *Climate Extremes Data and Communication Products for Western Adaptation Alliance Cities in the Intermountain Southwest*. Climate Assessment for the Southwest, University of Arizona: Tucson, AZ.
- Littell, J., G. Pederson, S. Gray, M. Tjoelker, A. Hamlet, and C. Woodhouse. (In Press). Reconstructions of Columbia River streamflow from tree ring chronologies in the Pacific Northwest, USA. *Journal of the American Water Resources Association*.
- Parris, A., G. Garfin, K. Dow, R. Meyer, and S. Close. 2016. *Climate in Context: Science and Society Partnering for Adaptation*. New Jersey: Wiley Ltd. & Sons.

- Meadow, A., Z. Guido, M. Crimmins, and J. McLeod. 2016. From principles to action: Applying the National Research Council's principles for effective decision support to the Federal Emergency Management Agency's watch office. *Climate Services* 1:12–23. doi: 10.1016/j.cliser.2016.02.002
- Meadow, A., E. McNie, J. Berggern, R. Norton, B. McMahan, G. Owen, and L. Rae. 2016. *NOAA Western Region Climate Service Providers Database Development and Preliminary Analysis*. Report.
- Overpeck, J. 2015. Viewpoints: Is Arizona facing a megadrought? *The Arizona Republic*, November 1. <http://www.azcentral.com/story/opinion/op-ed/2015/11/01/arizona-megadrought/74882132/>
- Routson, C., J. Overpeck, C. Woodhouse, and W. Kenney. 2016. Three Millennia of Southwestern North American Dustiness and Future Implications. *PLOS ONE* 11(2):e0149573.
- Springer, A., D. Swann, and M. Crimmins. 2015. Climate Change Impacts on High Elevation Saguaro Range Expansion. *Journal of Arid Environments* 116:57–62. doi:10.1016/j.jaridenv.2015.02.004.
- Wilder, M., D. Liverman, L. Bellante, and T. Osborne. 2016. Southwest climate gap: Poverty and environmental justice in the U.S. Southwest. *Local Environment: The International journal of Justice and Sustainability* 1-22. doi: <http://dx.doi.org/10.1080/13549839.2015.1116063>
- Woodhouse, C., G. Pederson, K. Morino, S. McAfee, and G. McCabe. 2016. Increasing influence of air temperature on upper Colorado River streamflow. *Geophysical Research Letters* 43. doi:10.1002/2015GL067613.